Information Processing in Dopant Network Processing Units

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Throughout history, man has exploited matter to carry out tasks well beyond his biological constraints. Starting from primitive tools with functionality solely derived from shape and structure, we have moved on to responsive matter that can react to an external stimulus and even further to adaptive matter that can change its response depending on the environment. One of the grand scientific and intellectual challenges is to make matter that can actually *learn*. Such matter's behavior would not only depend on the here and now, but also on its past. It would have long-term memory, and ultimately autonomously interact with its environment and self-regulate its action. We may call such matter 'intelligent'[1,2].

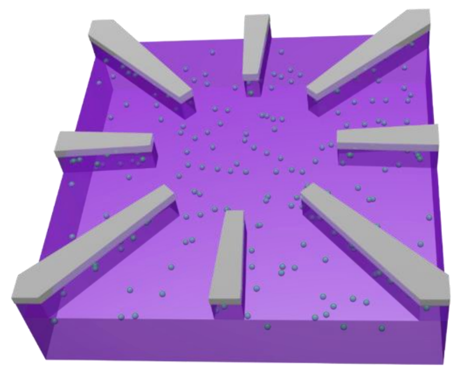

Figure 1. Schematic representation of a dopant network processing unit (DNPU). Silicon is lightly doped with boron, arsenic or phosphorus. Transport through the network of these dopants in combination with defect states gives rise to strongly nonlinear characteristics between inputs and outputs, which are tunable by the remaining control electrodes. The central area is typically 250 nm in diameter.

Here we introduce a number of experiments on disordered nanomaterial systems, where we make use of "material learning" to realize functionality. We have earlier shown that a 'designless' network of gold nanoparticles can be configured into Boolean logic gates using artificial evolution[3]. We later demonstrated that this principle is generic and can be transferred to other material systems. By exploiting the nonlinearity of a nanoscale network of dopants in silicon, referred to as a dopant network processing unit (DNPU), we can significantly facilitate handwritten digit classification[4]. An alternative material-learning approach is followed by first mapping our DNPU on a deep-neural-network model, which allows for applying standard machine-learning techniques in finding functionality[5]. Multi-DNPU networks can solve more complex tasks than individual DNPUs[6,7]. Finally, we show that our devices are not only suitable for solving static problems but can also be applied in highly efficient real-time processing of temporal signals at room temperature.

References

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